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DYNAMICS OF SUBSONIC TRACER PROJECTILES.(U)
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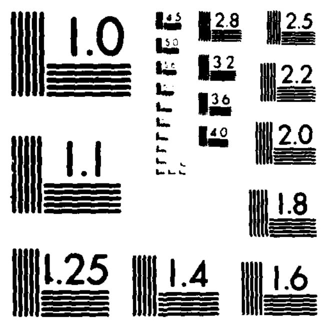

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DYNAMICS OF SUBSONIC TRACER PROJECTILES

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ABSTRACT

An evaluation of four tracer rounds at subsonic Mach numbers has been conducted. This evaluation indicated that three of the four subsonic tracer rounds possessed large dispersion characteristics. The fourth round, the 7.62 mm NATO round, has acceptable dispersion characteristics; however, even this round demonstrated a dynamic instability at the subsonic Mach numbers. It was found that this instability can be characterized by a growing precessional vector and it is present with or without the tracer ignited. Data indicated that the instability is tolerable when the tracer is ignited because of its small effect on the dispersion of the round.

INTRODUCTION

The VIPER antiarmor weapon system is being developed by the General Dynamics Pomona Division for the U.S. Army, MIRADCOM, Redstone Arsenal, Huntsville, AL. The tactical rocket is a tube launched, shoulder fired, 2.75 inch diameter rocket containing a shaped charge warhead. For training purposes a system was proposed whereby the troops could gain experience in estimating target speed, range, etc., at one thousandth the operational cost of the tactical round. This training system consists of a standard small caliber tracer round which would duplicate as near as possible the trajectory of the tactical rocket at subsonic Mach numbers.

There were four tracer rounds which appeared to be the most likely candidates for the training application. These four candidates were the .45 Cal ACP, the .30 Cal Carbine, the 5.56 mm, and the 7.62 mm NATO round. A search of the literature for subsonic flight characteristics of the subject rounds showed either incomplete data or no data available. The data that existed were obtained primarily at higher Mach numbers (Refs 1 and 2). In order to generate computer trajectory simulations for the candidate rounds, subsonic aerodynamic data (primarily drag) were required to best match the trajectory of the tactical rocket. Also, concern existed about the dispersion of the four candidate rounds at extended ranges of up to 500 meters.

TEST DESCRIPTION

The aerodynamic tests were conducted at the Aeroballistic Research Facility (ARF) and the dispersion tests were conducted at the Ballistic Experimentation Facility (BEF). Both of the facilities are managed and operated by the Air Force Armament Laboratory and are located at Eglin AFB Florida. The ARF is an enclosed, atmospheric, instrumented, concrete structure used to examine the exterior ballistics of various free-flight munitions. The range has 131 locations as instrumentation sites. Each location has a physical separation of 1.5 meters and presently 50 of the sites are used to house fully instrumented orthogonal shadowgraph stations. The nominal operating temperature of the range is 22° Celius. For a complete description of the ARF see Reference 3. The BEF is an outdoor range located on Test Area A22 and consists of concrete gun pads, large open area, and projectile impact revetments along with limited instrumentation.

The aerodynamic data were obtained using classical data reduction procedures, see References 4 and 5, and six degree of freedom numerical integration data reduction techniques as outlined in References 6 and 7. The numerical integration technique determines the aerodynamic coefficients and derivatives directly from the fitted motions; thereby, eliminating the rotating vectors analogy inherent in the classical data reduction procedure.

All the drag data obtained during the Phase I firing in the ARF were obtained using a simplified distance time analysis. The distance data were not obtained by computing the projectiles position as measured from the shadowgraph film as is the normal procedure. These distance data were obtained by measuring the distance between infrared (IR) light screens and the associated times were those corresponding to the IR screen sensor pulses. This initial approach to the test program was dictated by the fact that many rounds were to be fired in a short period of time and that initially only the total average drag coefficients were of concern. For a complete description of the tests and all the results obtained see Reference 8.

TEST RESULTS

The 5.56MM projectiles were test fired at the ARF to establish the CD coefficient at various Mach numbers for input to the computer simulation. Figure 1 is the CD profile from these tests and Figure 2 is a shadowgraph of the 5.56MM bullet at the 200 m. station showing the angle of attack developed by this range.

The .45 cal projectiles were similarly tested in the ARF. Due to the age of the cartridges the tracer failed to ignite in about 50% of the firings. When the tracer did not ignite the flight was more erratic. Outdoor firings were also conducted at the BEF where the trajectory was shown to be unsatisfactory (a growing spiral after about 300 meters). The same results were encountered with the .30 cal carbine projectile. Figure 3 is the CD profile for the .45 caliber tracer bullet. No CD profile is available for the .30 cal carbine tracer bullet as it was too unstable to be fired in the ARF.

The firings of the 7.62MM M-62 tracer at the BEF did not show the instability displayed by the other rounds. The 7.62MM bullet became the preferred bullet for the Viper tracer trainer. Sufficient firings were then conducted at the ARF to develop the data required. Figure 4 is a typical velocity versus range data collection for the 7.62MM projectile. The scatter is caused by the interaction of the tracer light with the IR screens. Figure 5 is the CD profile for the 7.62MM, M-62 tracer bullet.

As mentioned before, when the tracer failed to ignite, the 7.62MM rounds experienced an obvious and severe motion amplitude growth. It should be noted that only a small percentage of the tracers failed to ignite properly. However, since the cause of this motion growth phenomenon was unknown and the result severe, it seemed prudent to fire ten additional 7.62MM rounds in the ARF (Phase II) and extract all the aerodynamic coefficients and derivatives in order to investigate this phenomenon. These ten 7.62MM M-62 rounds were fired from a .30 cal carbine barrel (1 turn in 10 inches) using a standard .30 cal carbine case loaded with 4.8 grains of Unique® propellant. The tracer was not permitted to ignite on five of the rounds by applying a thin coat of Silastic 140 RTV Adhesive/Sealant® to the base of the rounds. The other five rounds were fired without any modification and the tracer ignited normally.

A summary of the classical Linear Theory results for the five 7.62MM rounds with the tracer ignited are shown in Table 1. A typical angular motion pattern for one of these rounds is shown in Figure 6. As can be seen from Table 1, the magnitude of the nutational vector (K10) is much smaller than the magnitude of the precessional vector (K20). Also, the damping rate of the precessional vector (L2) is positive for all rounds except for the round experiencing the smallest angles of attack. However, the typical motion pattern shown in Figure 6 indicates that the nutational vector is obviously damped (negative value of L1). For this condition, where the nutational vector is small and decreasing and the precessional vector is large and increasing, the angular motion pattern tends to become an ever increasing circle. For the rounds where the tracer is ignited this undamped precessional vector develops into angles of attack of about 10 degrees during the measured portion of the flight.

A summary of the classical Linear Theory results for the five 7.62MM rounds for which the tracer did not ignite is shown in Table 2. A typical motion pattern for one of these rounds is shown in Figure 7. All the comments made previously concerning the rounds where the tracer ignited hold for these "tracer off" rounds as well except for one significant difference. This difference is that the damping rate of the precessional vector (see L2 in Table 2) is much larger (still positive) than previously indicated in Table 1. This large positive value for L2 causes the aforementioned circular motion pattern to develop much faster and culminates in larger angles of attack.

Since the angular motions for both "tracer on" and "tracer off" rounds are characterized by the precessional vector and its downrange growth coupled with the nutational vector, predictions of the total angle of attack as a function of distance can be accurately made by ignoring the nutational vector and considering the precessional vector only. This prediction has been accomplished and is shown in Figure 8. The curves shown in Figure 8 were computed with the following relation

$$K_p = (K20)d^{(L2)X}$$

where

K20 = Initial amplitude of the precessional vector (assumed to be 5.73 degrees)

L2 = Average of the precessional damping rates as shown in Table 1 and Table 2

X = Downrange distance

The curves shown in Figure 8 show that the typical "tracer off" rounds reach a total angle of attack of 90 degrees prior to traveling 1640 ft (500M). It is not believed that the rounds actually tumble end over end but most likely remain in a "flat spin" condition. The curve in Figure 8 showing a typical "tracer on" round also indicates that the motion is growing; however, the maximum angle of attack expected at 500 meters is about 20 degrees. The outdoor firings indicate that this angle of attack (20 degrees) does not severely affect the dispersion of the rounds at 500 meters.

It is not known why the burning tracer has the effect of decreasing the dynamic instability of the 7.62MM rounds at subsonic Mach numbers, it is suspected that a jet damping effect could be acting or perhaps a wind vane effect caused by the tracer plume.

CONCLUSIONS

In summary the following conclusions can be made.

1. The 7.62MM tracer round is dynamically unstable at subsonic Mach numbers, with or without the tracer ignited.

2. The dynamic instability is decreased when the tracer is ignited.

3. The angular motion of the round with or without the tracer ignited, can be characterized by a growing precessional vector.

4. The dynamic instability for the "tracer on" rounds is acceptable because of its small effect on the dispersion.

5. The .30 cal carbine, .45 cal ACP and the 5.56 MM tracer rounds have very poor low velocity stability characteristics and therefore are not suitable for the Viper tracer trainer application.

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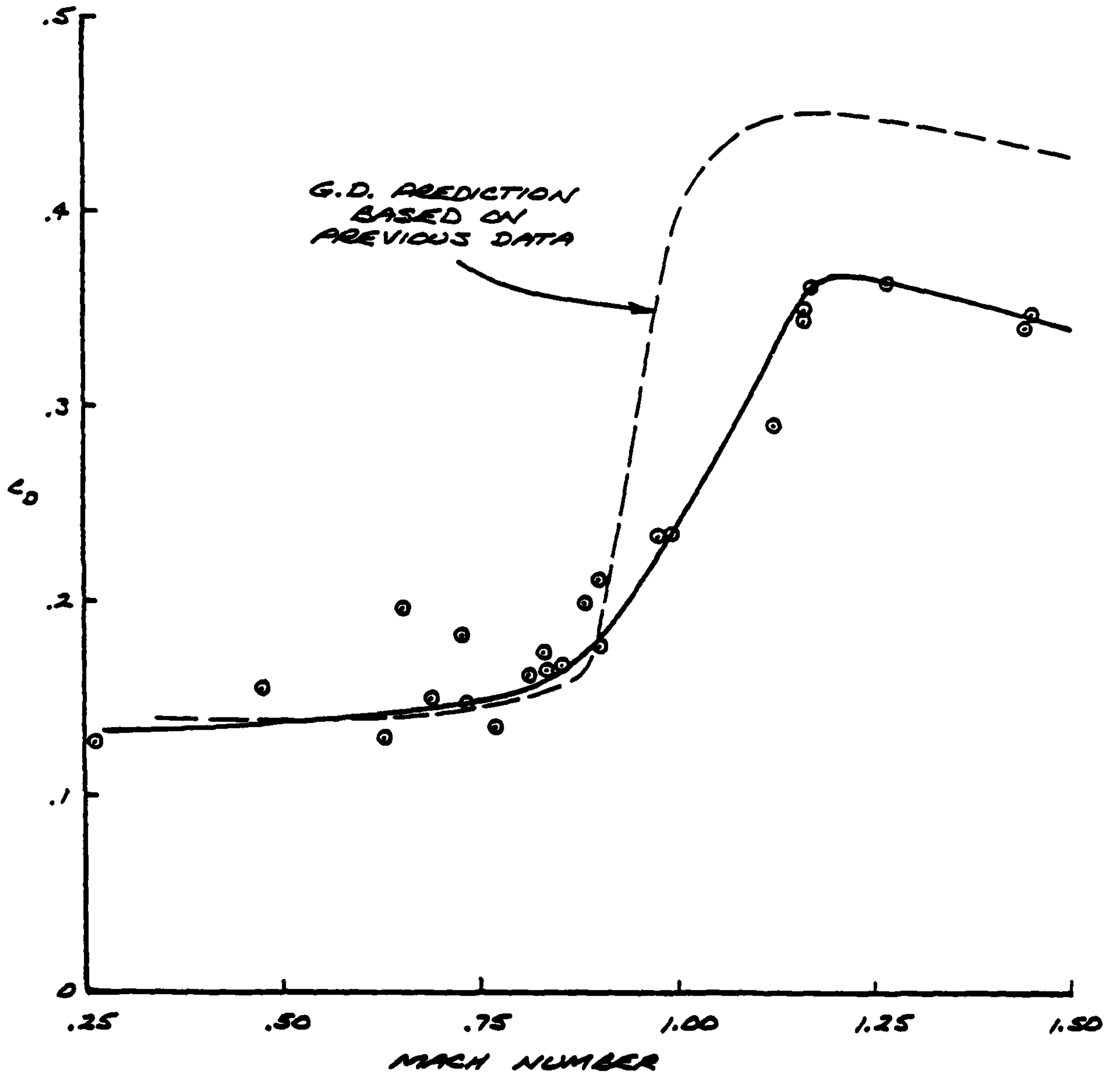
Table 1. Linear Theory Results for Five 7.62MM Rounds with "Tracer ON"

Shot No.	Mach	DBSQ DEG2	K10 DEG	K20 DEG	L1 1/M	L2 1/M	W10 Deg/M	W20 Deg/M	WD1 Deg/M	WD2 Deg/M
S79060732	.840	73.7	1.57	6.52	-.00656	.00680	142.347	21.511	0.00000	.00893
S79060733	.816	42.7	.60	5.71	-.00656	.00328	145.368	22.943	0.00000	-.03737
S79060735	.801	5.3	.49	3.00	-.00656	-.00316	145.508	23.214	0.00000	-.00995
S79060838	.811	74.7	.35	8.29	-.00656	.00112	143.812	22.195	0.00000	-.00768
S79061142	.770	76.2	.87	6.06	-.00656	.00417	141.831	21.743	0.00000	-.01111

Table 2. Linear Theory Results for Five 7.62MM Rounds With "Tracer OFF"

Shot No.	Mach	DBSQ DEG2	K10 DEG	K20 DEG	L1 1/M	L2 1/M	W10 Deg/M	W20 Deg/M	WD1 Deg/M	WD2 Deg/M
S79060731	.693	113.4	.05	5.40	-.00656	.00838	147.146	20.201	0.00000	-.01833
S79060837	.810	156.0	1.00	5.54	-.00656	.01048	145.341	21.914	0.00000	-.04266
S79061139	.746	148.0	1.03	6.86	-.00656	.00563	143.769	21.299	0.00000	-.02487
S79061140	.733	308.8	.72	5.47	-.00656	.01034	145.341	22.272	0.00000	-.04927
S79061141	.749	141.7	.11	5.77	-.00656	.00718	141.207	19.781	0.00000	-.02185



5.56 TRACER ROUNDS

Figure 1

C_D VS Mach No. 5.56 mm Tracer Bullet

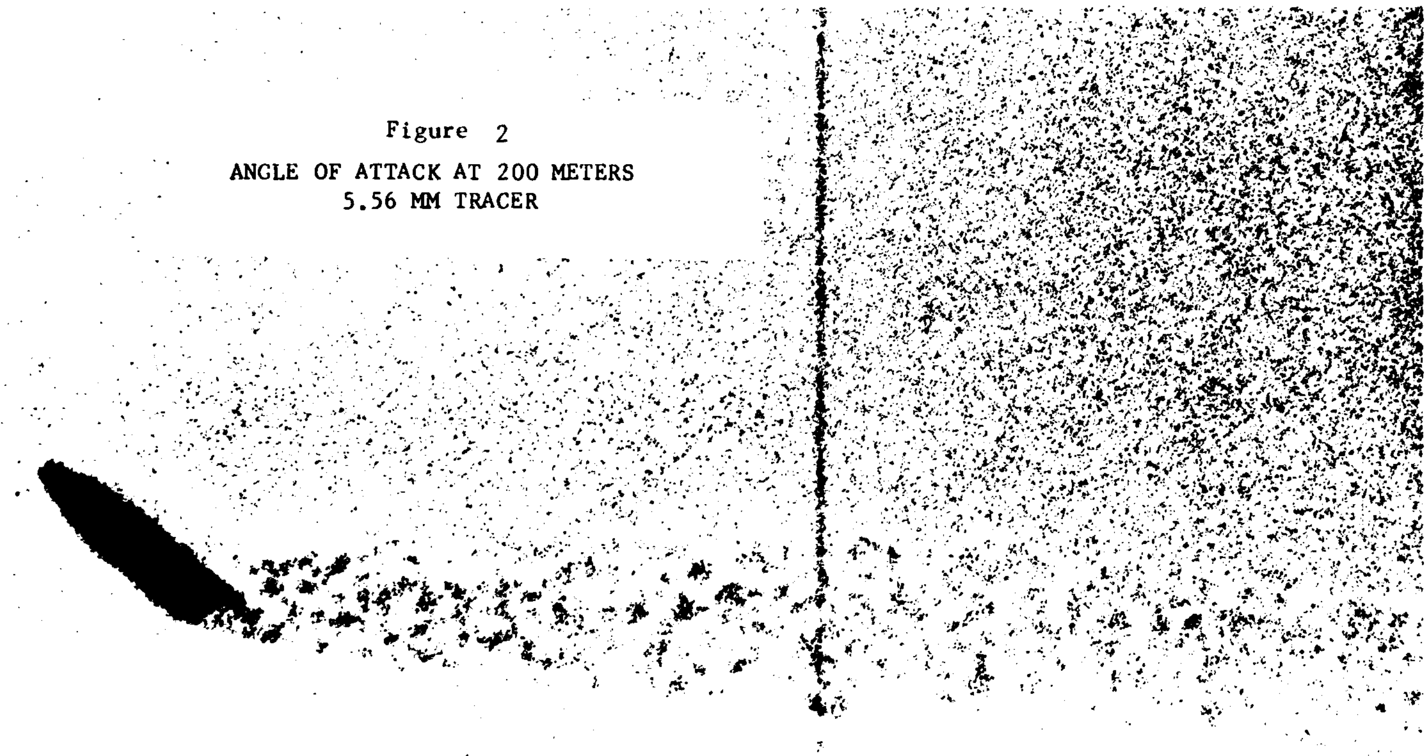


Figure 2

ANGLE OF ATTACK AT 200 METERS
5.56 MM TRACER

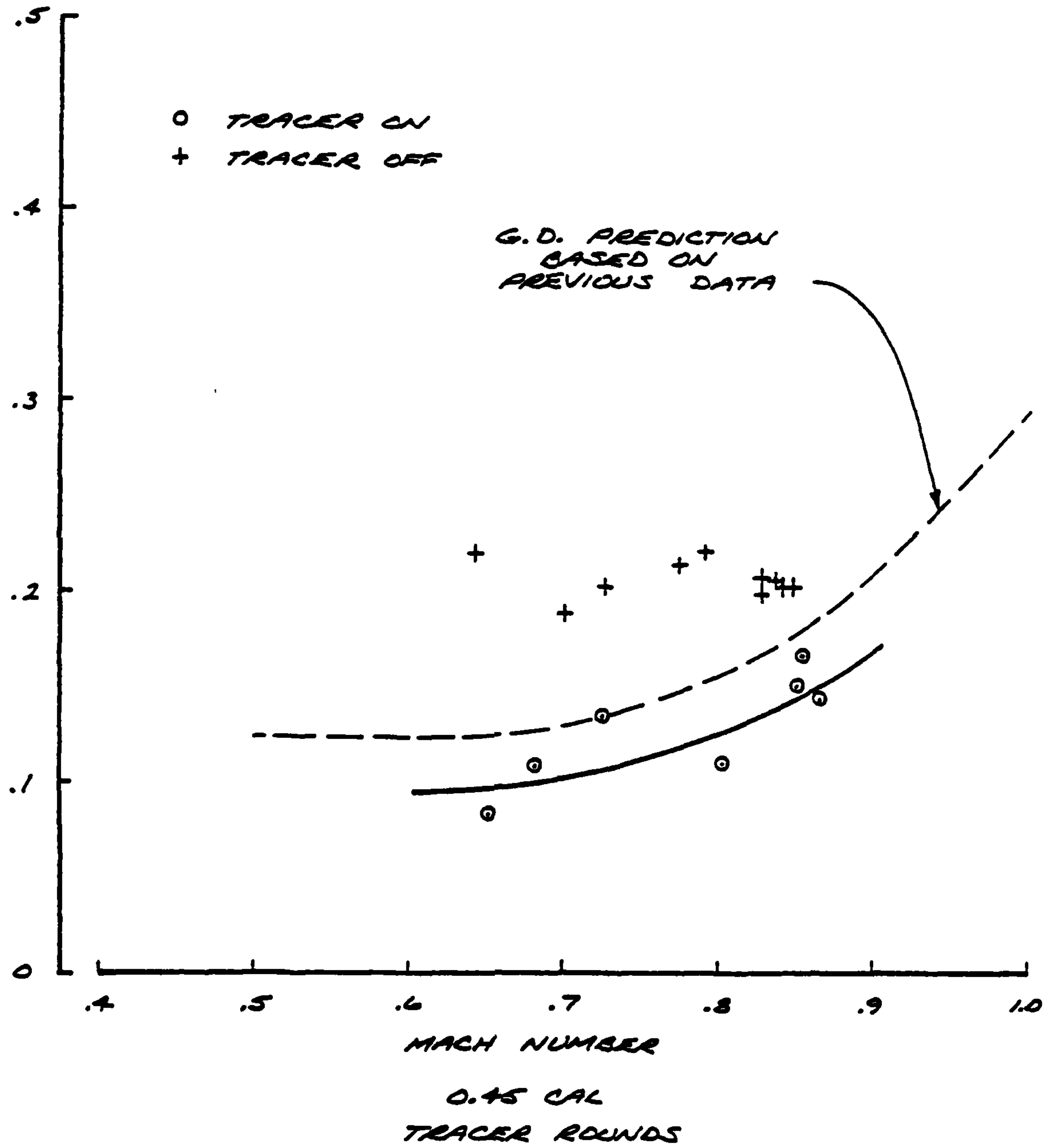


Figure 3

C_D VS Mach No. .45 Caliber Tracer Bullet

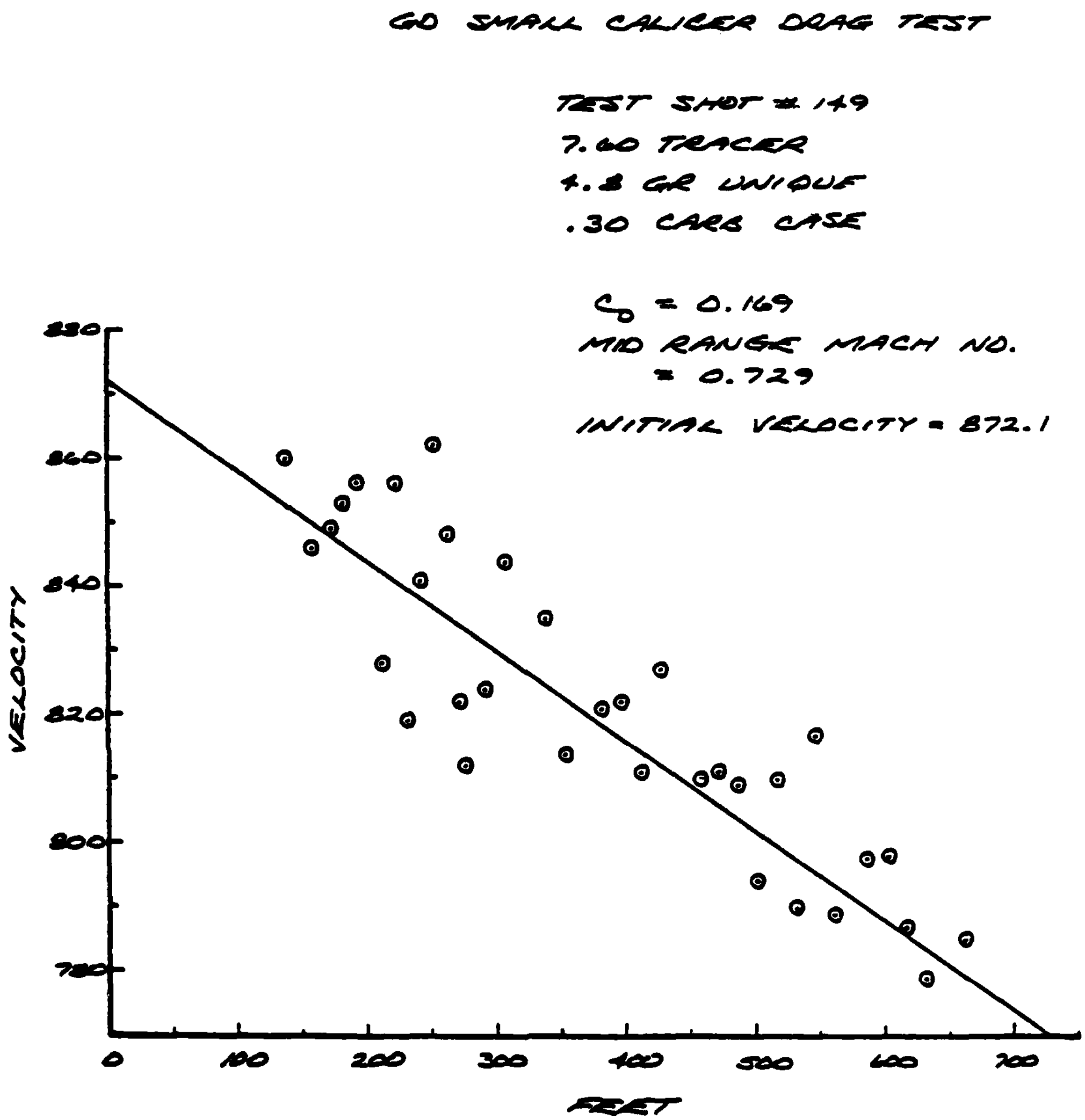


Figure 4

Typical Velocity VS Range Plot to a 7.62 mm Tracer Bullet Test

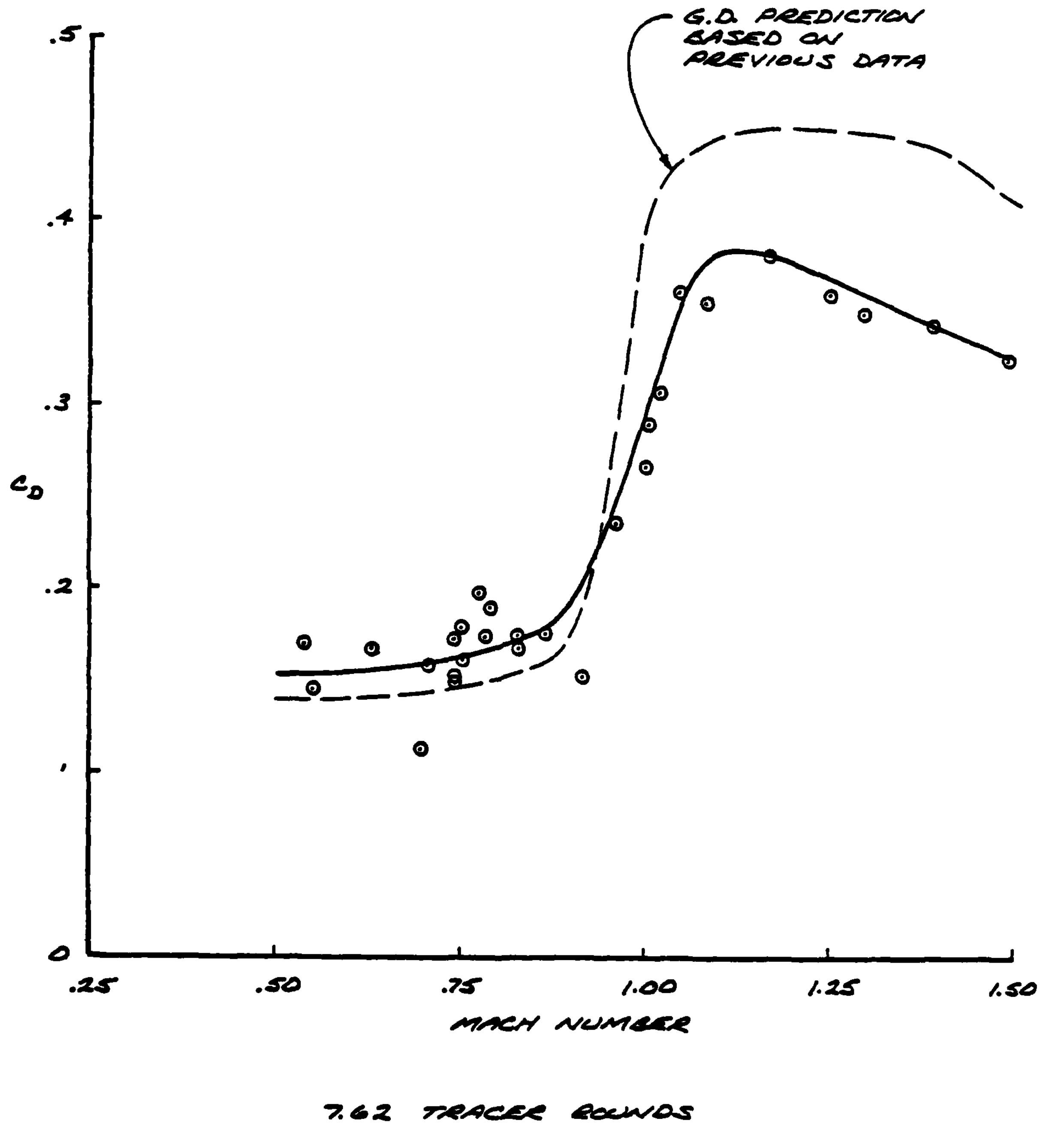
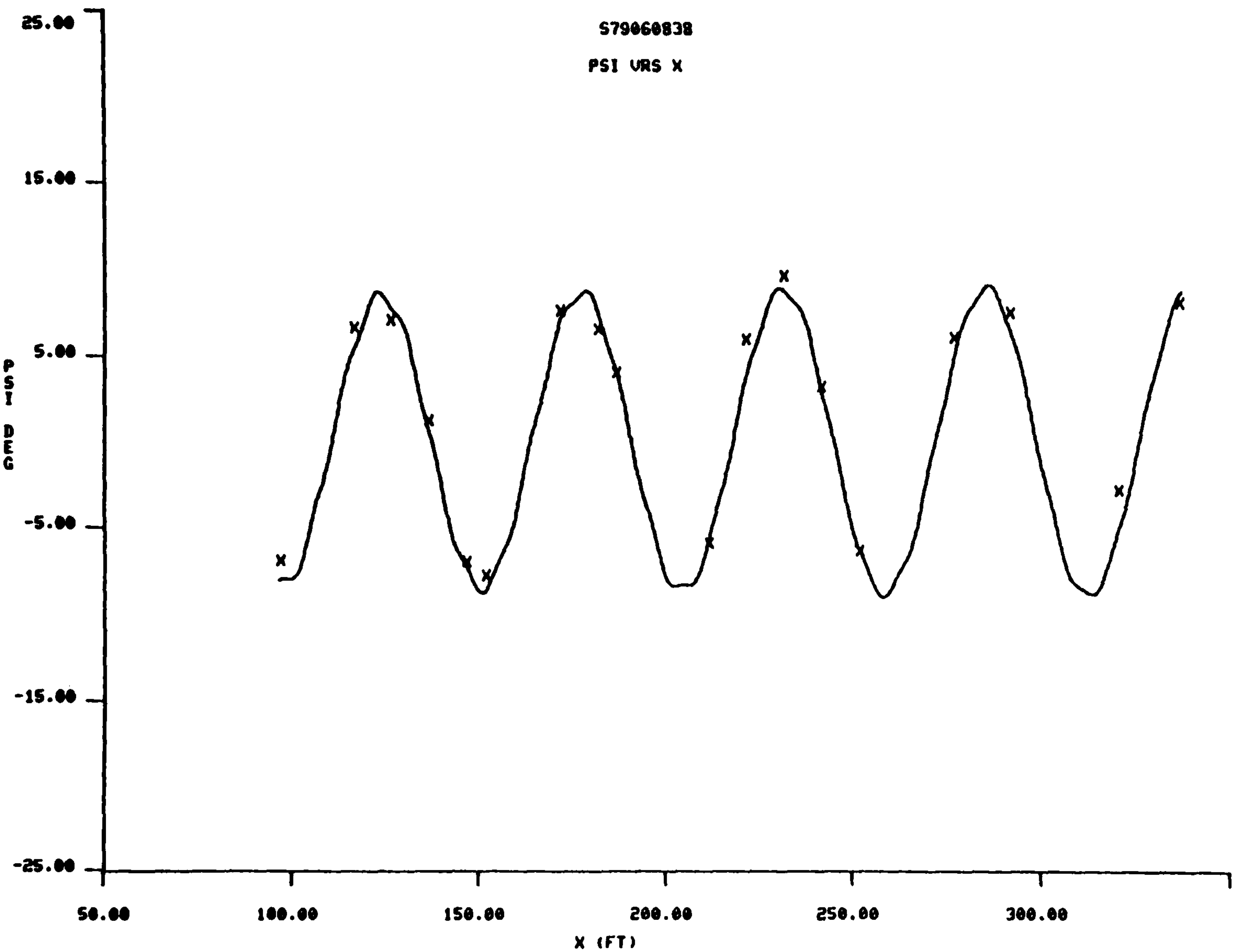


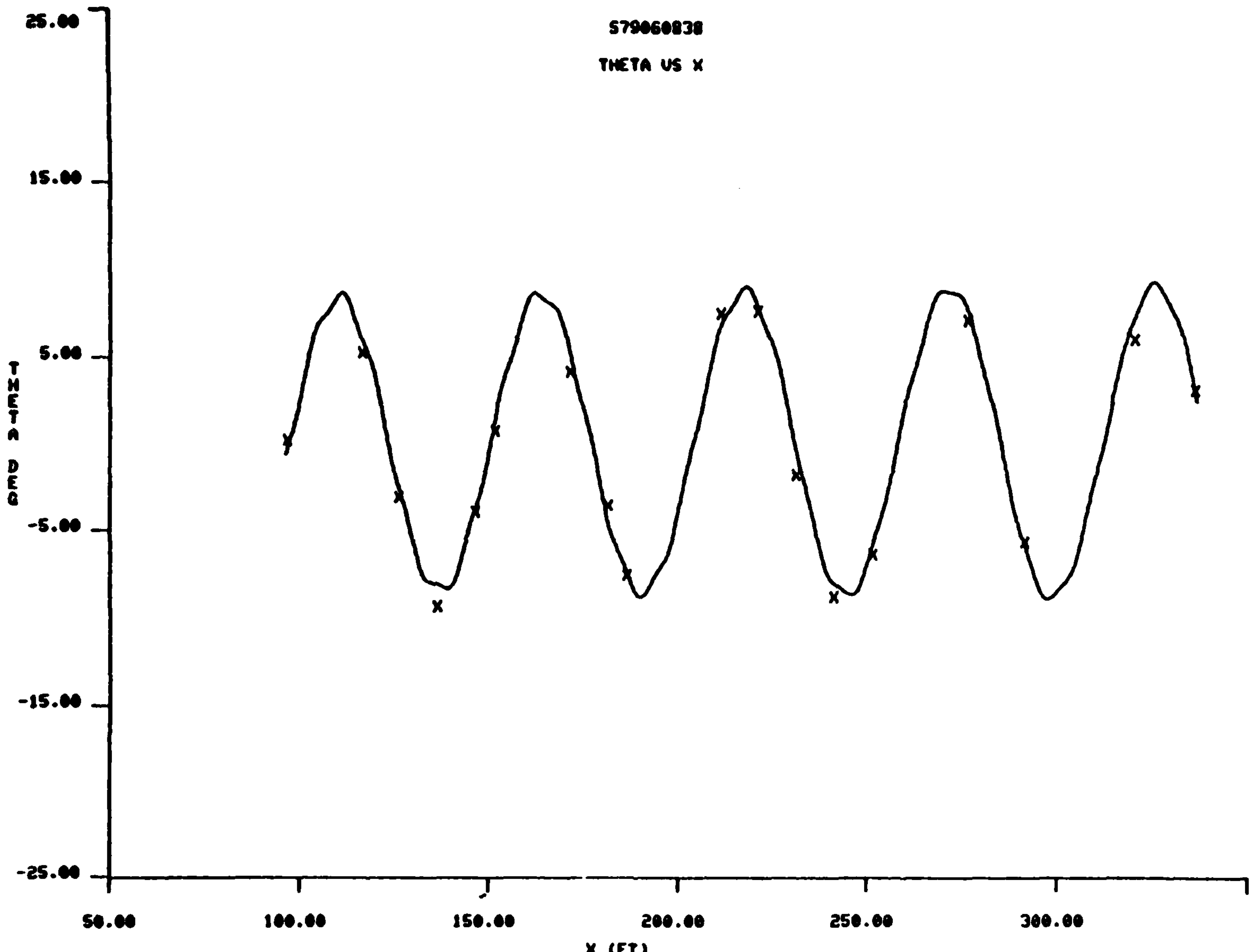
Figure 5

C_D VS Mach No. 7.62 mm Tracer Bullet



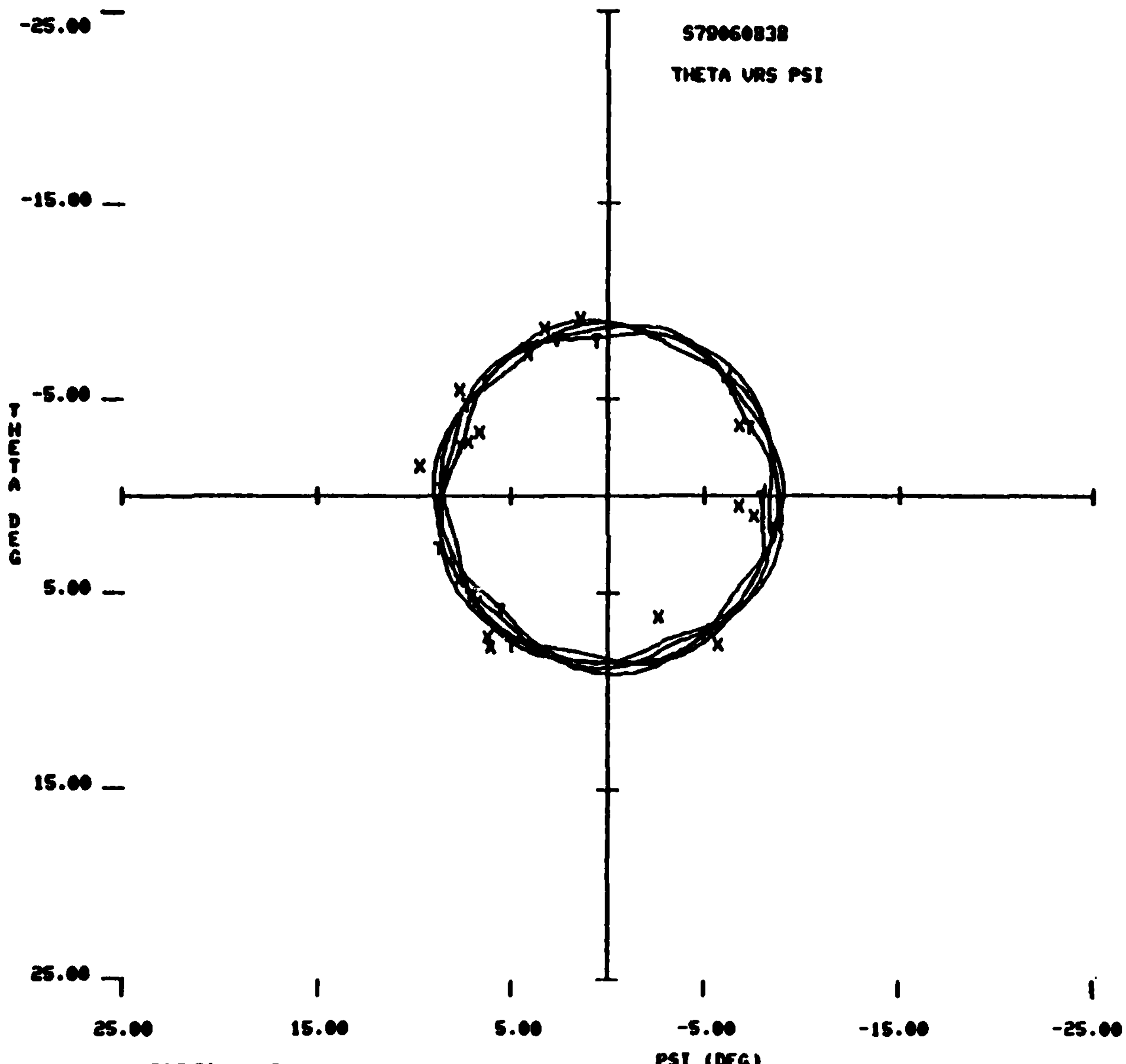
a. PSI vs DISTANCE

FIG 6. TYPICAL MOTION PATTERN FOR "TRACER ON" ROUNDS



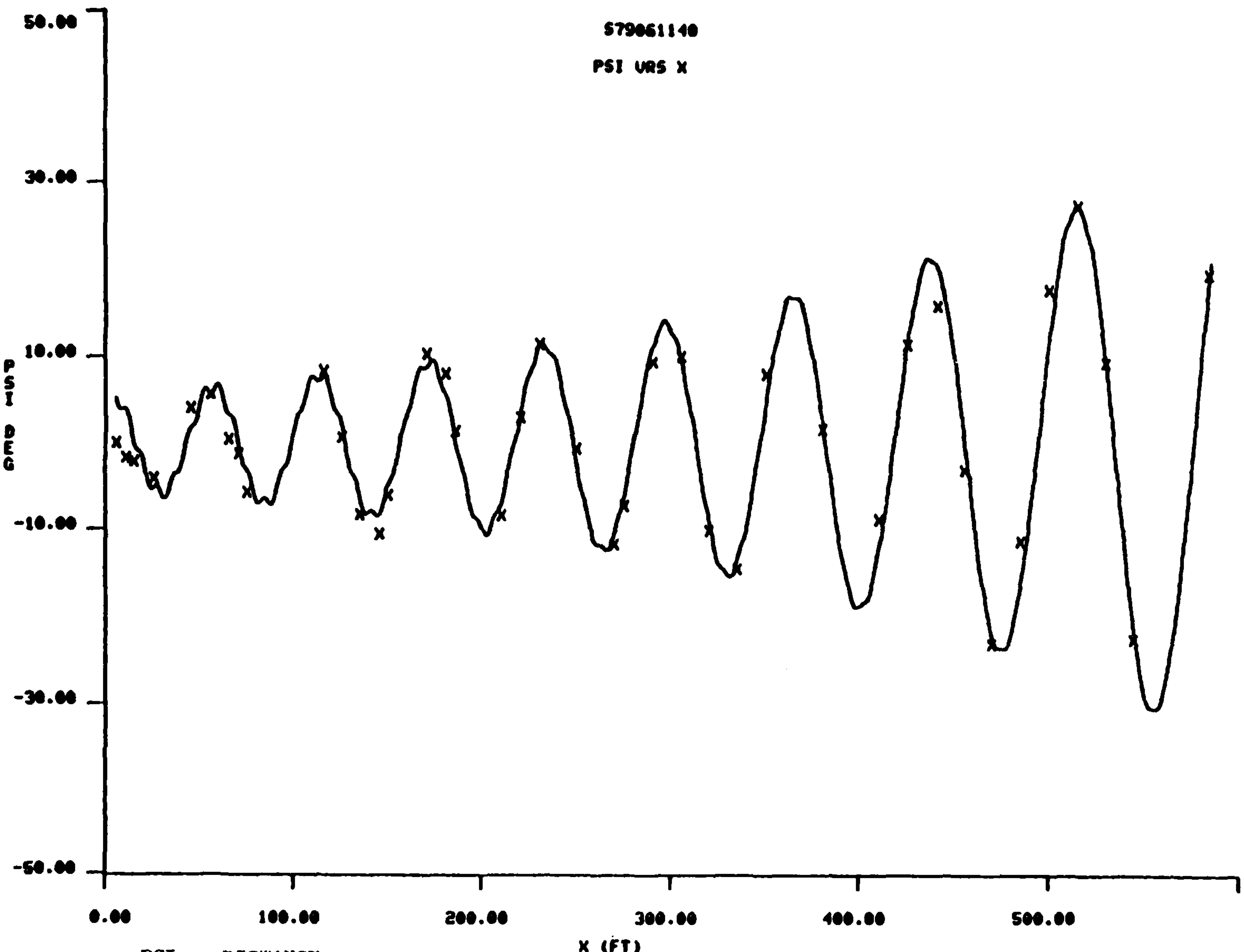
b. THETA vs DISTANCE

FIG 6 (CONTINUED)



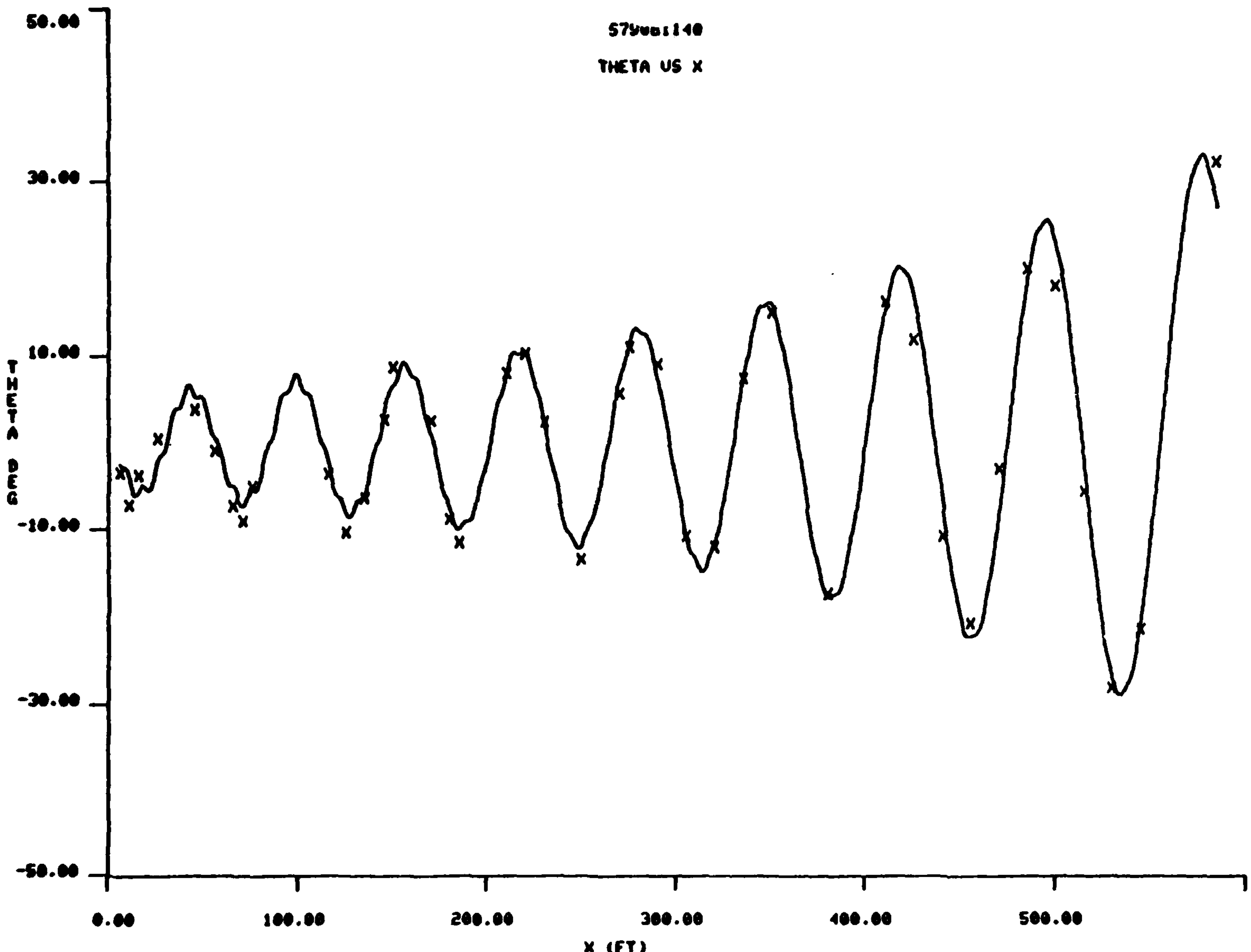
a. THETA vs PSI

FIG 6 (CONCLUDED)



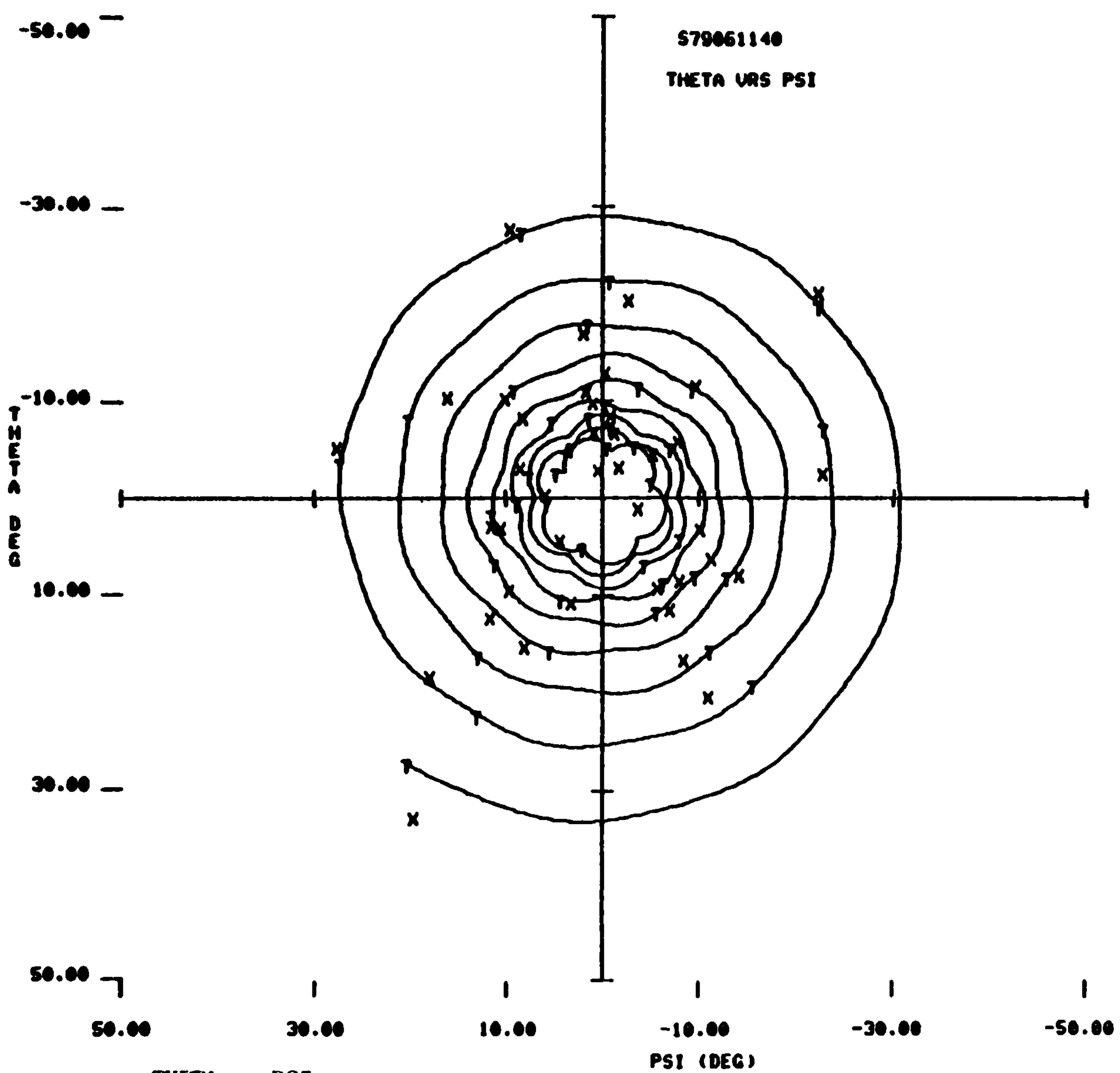
a. PSI vs DISTANCE

FIG 7. TYPICAL MOTION PATTERN FOR "TRACER OFF" ROUNDS



b. THETA vs DISTANCE

FIG 7 (CONTINUED)



c. THETA vs PSI

FIG 7 (CONCLUDED)

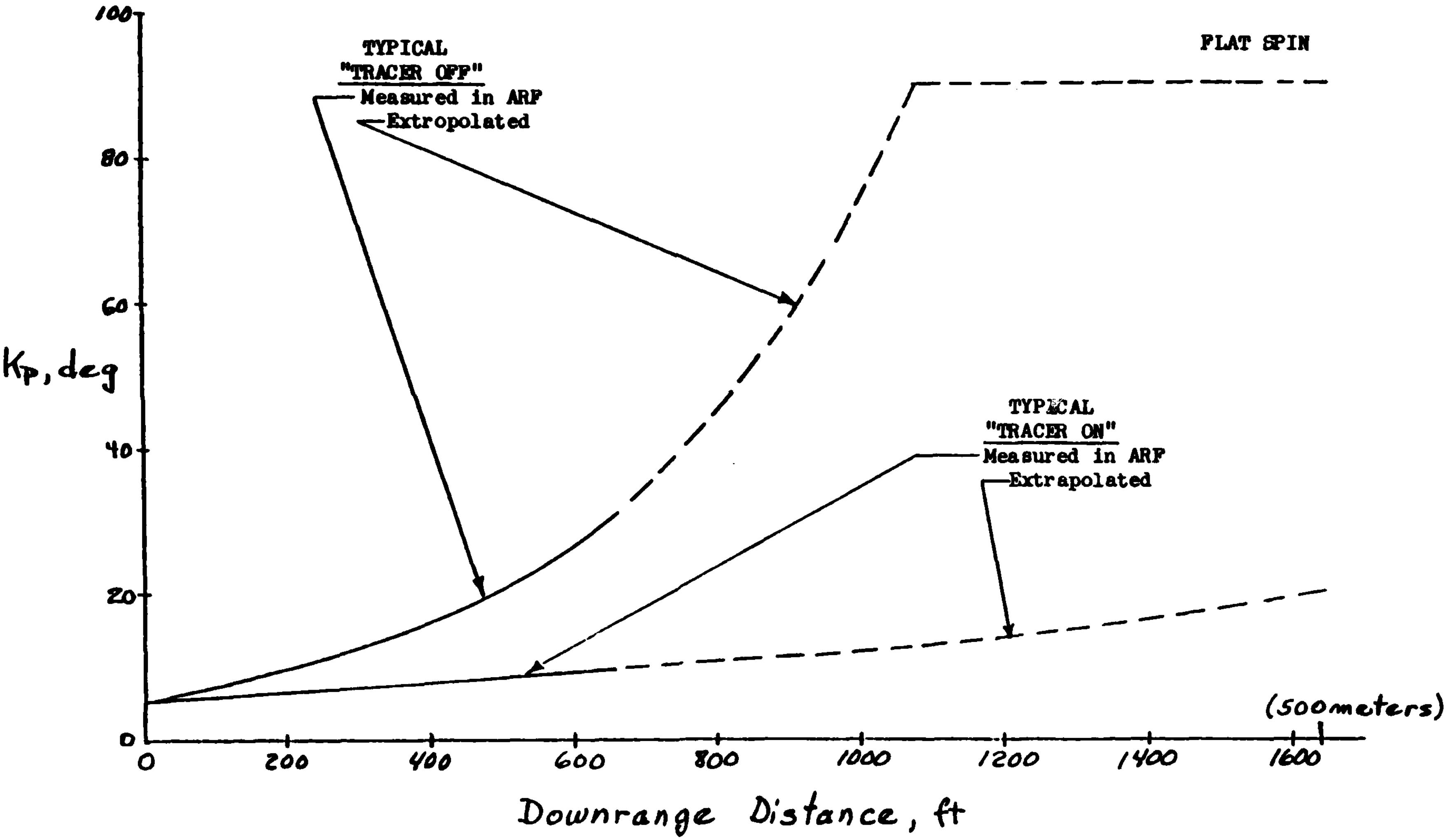


FIG 8. TYPICAL MOTION GROWTH OF PRECESSIONAL VECTOR

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